THE DYNAMIC PLASMA AND ELECTRIC FIELD ENVIRONMENT NEAR THE LUNAR TERMINATOR AND POLAR REGIONS. J. S. Halekas[1], G.T. Delory[1], T.J. Stubbs[2,3], W.M. Farrell[2], and R.P. Lin[1,4], [1]Space Sciences Laboratory, U.C. Berkeley, [2]NASA Goddard Space Flight Center, [3]University of Maryland, Baltimore County, [4]Physics Department, U.C. Berkeley. Corresponding author's e-mail: jazzman@ssl.berkeley.edu.

Introduction: The Moon has a dynamic near-surface plasma and electric field environment, with no global magnetic field, and only a minimal exosphere, to shield it from the ambient space environment. The highly variable plasmas encountered by the Moon in the solar wind and terrestrial magnetosphere drive surface charging which varies over orders of magnitude, with surface electrostatic potentials reaching values as large as -5 kV during particularly disturbed conditions.

The region near the terminator (and poles) is a particularly dynamic zone, with (at least) two fundamental physical processes that produce local electric fields:

(1) Surface charging changes sign near the optical terminator, with the surface generally charging positive in the sunlit hemisphere and negative in the shadowed hemisphere, likely leading to strong local electric fields near the transition region.

(2). The boundary of the lunar wake, a poorly understood region with strong ambipolar electric fields, intersects the surface at and extends downstream from the flow terminator.

These two fundamental physical processes interact and couple in an unknown fashion, and produce local electric fields which may significantly affect the motion of charged particles and dust near the surface. A complete understanding of the lunar terminator environment is not possible without a thorough characterization of these processes. In addition, near-surface plasma and electric fields in this zone, and their likely role in dust electrification and transport, may have important implications for surface exploration, with its likely focus on the polar regions.

Background: Theoretically, the Moon should charge to small positive values of ~+5-10V on the sunlit hemisphere (where photoemission dominates), and to larger negative values of ~-100V on the shadowed hemisphere (where photoemission is absent, and plasma currents dominate) [1,2]. These expectations have been largely borne out by observations on the surface by the ALSEP package [3] and by electron reflectometry from orbit by Lunar Prospector (LP) [4]. However, LP observations have also revealed that the surface can charge to kV-scale potentials when the Moon encounters energetic plasmas in the terrestrial plasmasheet [5] or during solar energetic particle (SEP) events [6]. Recent results from a new analysis of LP data, taking into account spacecraft charging and utilizing improved techniques to remotely sense lunar potentials, have produced a more quantitative understanding of lunar surface charging [7], but many puzzles remain, especially near the terminator.

The lunar wake constitutes an additional source of electric fields in this fascinating region. Solar wind plasma impacts the Moon on the upstream side, forming a plasma void extending downstream from the Moon. As plasma fills in this void region, the faster electrons stream into the wake, creating ambipolar electric fields across the wake boundary which act to prevent large departures from quasi-neutrality, slowing down the faster electrons and accelerating ions into the wake [8]. The wake boundary has been investigated in detail at altitudes of 10's of km, using LP data [9]. However, the region where the wake boundary meets the surface, and wake-generated electric fields interact with surface electric fields, remains poorly understood. Recent modeling suggests that electric fields in this region, (perhaps associated with local topography?) could have significant effects on dust motion [10].

Lunar Prospector Measurements: Fig. 1 shows surface potentials inferred from LP data in the solar wind and wake [7]. Note the rapid change from small (statistically indistinguishable from zero) potentials on the day side to negative potentials of 100's of V on the night side. The ~-200 V surface potentials near the terminator significantly exceed theoretical predictions, given measured electron temperatures of <~50 eV, requiring either very different electron and ion densities and/or temperatures, or some additional effect [7].

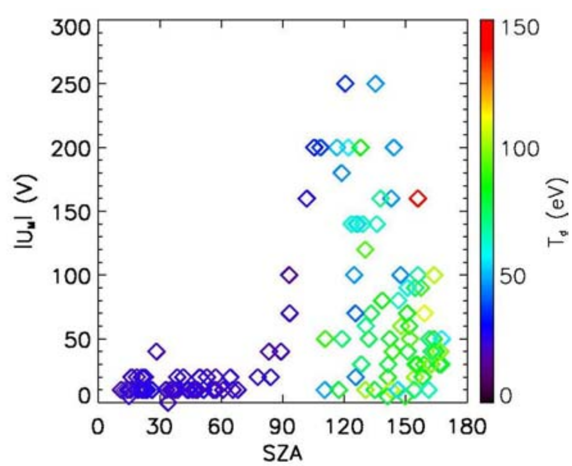

__Figure 1:__ Magnitude of inferred lunar surface potential as a function of solar zenith angle, colored according to electron temperature. Terminator lies at SZA=90.

As one possibility, we consider the effects of wake boundary electric fields near the terminator. Wake-associated fields produce an additional potential drop between the spacecraft and the near-surface plasma, thereby increasing the total potential drop to the surface measured by the reflectometry technique. To address this question, we used a simple theoretical self-similar model of wake expansion [5]. This model fits LP electron data very well, as shown in the first two panels of Fig. 2. The model predicts a potential difference between the near-surface plasma and the spacecraft location (shown in red in third panel of Fig. 2) which can explain some, but not all, of the large potential drop observed between orbital altitude and the surface. However, it is clear that wake-associated electric fields comprise an important component of the electric field environment near the terminator.

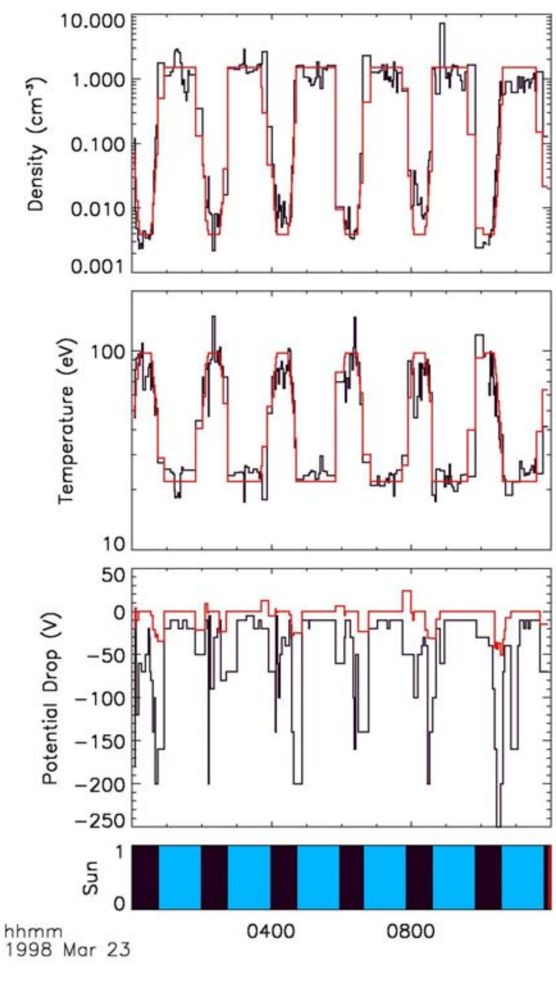

Figure 2: *Electron density and temperature, with model predictions in red, and potential drop between the spacecraft location and the surface, with model predictions of wake-associated potential drop in red.*

Implications for Exploration: In addition to the scientific importance of understanding these fundamental space plasma physics processes, near-surface plasma and electric fields in the terminator and polar regions have potentially significant implications for exploration, especially given the likely focus on the polar regions. Electric fields may affect machinery on the surface – this process has been demonstrated to be a leading cause of spacecraft failures in space [11]. In addition, surface electric fields also likely contribute to dust charging and transport. There is substantial observational support for dust levitation a few meters above the surface [12], and some evidence for dust transport to much greater altitudes [13] and highly accelerated dust [14]. Dust was a significant hindrance and hazard for astronauts during the Apollo programs [15], and must be reckoned with in future plans.

Conclusions: We investigate the complex and dynamic plasma and electric field environment near the lunar terminator, focusing on the combined effects of electric fields produced by surface charging and at the lunar wake boundary. This region remains poorly understood, and we will likely need in situ investigations to fully define the environment and the physical processes operating there. However, by utilizing Lunar Prospector data, we can provide some early constraints on the problem. Preliminary studies show that electric fields associated with both surface charging and with the lunar wake boundary contribute significantly to the electric field environment near the terminator and polar regions.

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